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Application of Genetic Algorithm for Power Flow Analysis

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Abstract

Power flow is nothing but the flow of active and reactive power . Power flow analysis is used to determine the steady state operating condition of a power system. In short it is to find the approximate values of various bus voltages, their phase angle, active and reactive power flows through different branches, generators and loads under steady state condition .Heuristic methods are generally referred as experience based techniques for solving problem, learning and discovery. Heuristics are simple and efficient rules coded by evolutionary processes. In this paper , GA , genetic algorithm ,one of such heuristic algorithms have been used to do the power flow analysis in a simple three bus system

1. Introduction

In a three phase ac power system active and reactive power flows from the generating station to the load through different networks buses and branches. The flow of active and reactive power is called power flow or load flow. Power flow studies provide asystematic mathematical approach for determination of various bus voltages, there phase angle active and reactive power flows through different branches, generators and loads under steady state condition. Power flow analysis is used to determine the steady state operating condition of a power system.[1,2,3] Power flow analysis is widely used by power distribution professional during the planning and operation of power distribution system.

- Load-flow studies are performed to determine the steady-state operation of an electric power system. It calculates the voltage drop on each feeder, the voltage at each bus, and the power flow in all branch and feeder circuits.
- Determine if system voltages remain within specified limits under various contingency conditions, and whether equipment such as transformers and conductors are overloaded.
- Load-flow studies are often used to identify the need for additional generation, capacitive, or inductive VAR support, or the placement of capacitors and/or reactors to maintain system voltages within specified limits.
- Losses in each branch and total system power losses are also calculated.
- Necessary for planning, economic scheduling, and control of an existing system as well as planning its future expansion

Power Flow Equation

$$I_i = y_{i0} V_i + y_{i1} (V_i - V_1) + \cdots + y_{in} (V_i - V_n) \quad (1)$$

$$I_i = (y_{i0} + y_{i1} + \cdots + y_{in}) V_i - y_{i1} V_i - y_{i2} V_2 - \ldots . - y_{in} V_n$$

$$I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \; ; \quad j \neq i \qquad (2)$$

The real and reactive power at bus *i* is

$$P_i - jQ_i = V_i I_i^* \qquad (3)$$

$$I_i = \frac{P_i - jQ_i}{V_i^*} \qquad (4)$$

Substituting for Ii in (2) yields

$$P_i - jQ_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \; ; \quad j \neq i \quad (5)$$

Equation (5) is an algebraic non linear equation which must be solved by iterative techniques

2. Gauss-Seidal Method

Equation (5) is solved for V_i *solved iteratively*

$$V_i^{(k+1)} = \frac{\frac{P_i^{sch} - Q_i^{sch}}{V_i^{(k)}} + \sum Y_{ij} V_j^{(k)}}{\sum y_{ij}} \quad ; \ j \neq i \qquad (6)$$

Where $\boldsymbol{y_{ij}}$ is the actual admittance in p.u. $\boldsymbol{P_i^{sch}}$ and $\boldsymbol{Q_i^{sch}}$ are the net real and reactive powers in p.u. In writing the KCL, current entering bus ***I*** was assumed positive. Thus for Generator buses (where real and reactive powers are injected), $\boldsymbol{P_i^{sch}}$ and $\boldsymbol{Q_i^{sch}}$ have positive values. Load buses (real and reactive powers flow away from the bus), $\boldsymbol{P_i^{sch}}$ and $\boldsymbol{Q_i^{sch}}$ have negative values Eqn.5 can be solved for $\boldsymbol{P_i}$ and $\boldsymbol{Q_i}$

$$P_i^{(k+1)} = R\left\{V_i^{*(k)}\left(V_i^{(k)} \sum_{j=0}^{n} Y_{ij} - \sum_{j=1}^{n} Y_{ij} V_j^{(k)}\right)\right\}; \ j \neq i \qquad (7)$$

$$Q_i^{(k+1)} = -Im\left\{V_i^{*(k)}\left(V_i^{(k)} \sum_{j=0}^{n} Y_{ij} - \sum_{j=1}^{n} Y_{ij} V_j^{(k)}\right)\right\}; \ j \neq i \qquad (8)$$

The power flow equation is usually expressed in terms of the elements of the bus admittance matrix, Y_{bus} , *shown by upper case letters, are* $Y_{ij} = -y_{ij}$, *and the diagonal elements are* $Y_{ii} = \sum y_{ij}$. *Hence eqn. 6 can be written as*

$$V_i^{(k+1)} = \frac{\frac{P_i^{sch} - Q_i^{sch}}{V_i^{(k)}} + \sum_{j \neq i}^{n} Y_{ij} V_j^{(k)}}{Y_{ii}} \quad ; \ j \neq i \qquad (9)$$

$$P_i^{(k+1)} = R\left\{V_i^{*(k)}\left(V_i^{(k)} Y_{ii} - \sum_{j=1 \neq i}^{n} Y_{ij} V_j^{(k)}\right)\right\}; \ j \neq i \qquad (10)$$

$$Q_i^{(k+1)} = -Im\left\{V_i^{*(k)}\left(V_i^{(k)} Y_{ii} - \sum_{j=1 \neq i}^{n} Y_{ij} V_j^{(k)}\right)\right\}; \ j \neq i \qquad (11)$$

2.A. Iterative Steps

- Slack bus: both components of the voltage are specified. 2(n-1) equations to be solved iteratively.
- Flat voltage start: initial voltage of 1.0+j0 for unknown voltages.
- PQ buses: $\boldsymbol{P_i^{sch}}$ and $\boldsymbol{Q_i^{sch}}$ are known. with flat voltage start, Eqn. 9 is solved for real and imaginary components of Voltage.
- PV buses: $\boldsymbol{P_i^{sch}}$ and [Vi] are known. Eqn. 11 is solved for $\boldsymbol{Q_i^{k+1}}$ which is then substituted in Eqn. 9 to solve for $\boldsymbol{V_i^{k+1}}$

The rate of convergence is increased by applying an acceleration factor (α) to the approx. solution obtained from each iteration.

$$V_i^{(k+1)} = V_i^{(k)} + \alpha(V_{ical}^{(k)} - V_i^{(k)}) \qquad (12)$$

This process continues till the convergence criterion is satisfied .Once a solution is converged, the net real and reactive powers at the slack bus are computed from Eqns.10 & 11.

2.B Computation Of Line Flows And Line Losses

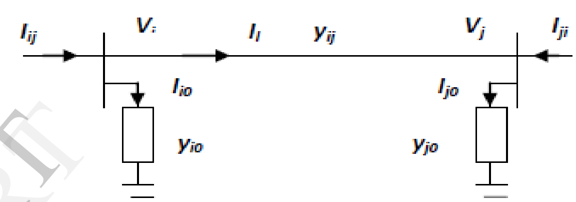

Fig. 1.

The complex power $\boldsymbol{S_{ij}}$ from bus i to j and $\boldsymbol{S_{ji}}$ from bus j to i are

$$S_{ij} = V_i I_{ij}^* \qquad (13)$$

$$S_{ji} = V_j I_{ji}^* \qquad (14)$$

Where

$$I_{ij} = y_{ij} \left(V_i - V_j\right) + y_{i0} V_i$$

$$I_{ji} = y_{ij} \left(V_j - V_i\right) + y_{i0} V_j$$

3. Genetic Algorithm (GA)

Genetic algorithm is based on the evolutionary ideas of natural selection and genetics. It is inspired by Darwin's theory of evolution – "survival of the fittest " i.e. survival of the fittest among the individual over consecutive generation for scanty resources. GA belongs to the larger class of evolutionary algorithms (EA) which involves selection , mutation and crossover . GA is good at taking large , potentially huge search space and navigates them to get optimal solution. GA is more flexible than most search methods because they require only information concerning the quality of the solution produced each parameter set and not like many optimization methods which require derivative information and complete knowledge of the problem structure and parameters[5]. On the other hand GA could have trouble in finding the exact global optimum and they require a large number of fitness functions evaluations.

GA is useful and efficient when:

i. The search space is large, complex or poorly understood.
ii. Domain knowledge is scarce or expert knowledge is difficult to encode to narrow the search space.
iii. No mathematical analysis is available.
iv. Traditional search methods fail.

The common terms which are generally used while solving problem using GA are:

A. Search space: The space of all feasible solutions which all desired solutions resides is called search space. Each point in the search space represents one possible solution which can be marked by its fitness value for the problem. GA looks for the best solutions among a number of possible solutions represented by one point in the search space. The process of finding solutions generates other solutions as evolution proceeds.
B. Population: it is the number of individuals present with the same length of solutions.
C. Fitness: it is the value assigned to an individual present with the same length of solution it contains.
D. Fitness function: it is a function that assigns fitness value to the individual . It is problem specific.
E. Selection : Selecting individual for creating the next generation .
F. Crossover: The main objective of crossover is to recognize the information of two different individuals and produce a new one.
G. Mutation: It is nothing but randomly changing the values in a solution. It is used to introduce some part of artificial diversification in the population to avoid premature convergence to local optimum.

The steps involved in Genetic Algorithm are as follows[11]:

1. Evaluate all the desired solutions with the fitness function, which can be the inverse of error function
2. Save the best solution.
3. Select some highly fit solutions.
4. Pair the selected solutions as parents and perform crossover operation to generate offspring.
5. Perform mutation by slightly changing some random solutions.
6. Replace the entire population with these offspring and the best solution.
7. Repeat above procedure until some stopping criterion is met.

4. Flowchart

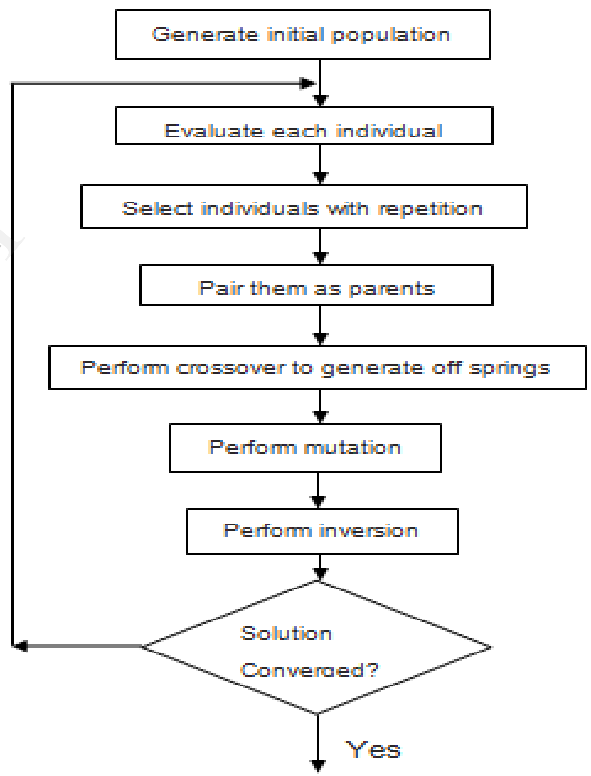

Fig.2 Flow chart for genetic algorithm

The flow chart of the simple genetic algorithm is shown above in the Fig.2. Here , the initial population can be random or user specified . After the reproduction , new generation will replace the old on and evolve until a stopping criterion is met.

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5. Results And Discussion

Here in the paper, a simple 3- bus system is considered for the power flow analysis. Let bus no. 1 is slack bus , bus 2 is a PQ bus and bus 3 is a PV bus. Firstly the program is executed for power flow using GS method using MATLAB. And the results are obtained which include P,Q,V and δ at all the busses. Now to find the the fitness function , error function is calculated as

$$Error\ function = \sqrt{\left((P_{2act} - P_{2cal})2 + (P_{3act} - P_{3cal})2 + (Q_{3act} - Q_{3cal})2\right)}$$

Results by GA :

1. We consider 10 initial solutions for each V2 , delta2 and delta3 according to their previous experience. For V2 , limits lies in between 0.8to 1.3 and for delta , between 1.00 to -20.00.
2. Evaluate all the solutions with the fitness function.
3. Select best 5 solutions according to their fitness values along with their repetition to form 10 solutions.
4. Except first two solutions paired the solutions as parents. Then crossover is done between the parents to get the off springs.
5. Then mutation is performed for some random solution and random parameters to slightly modify the solutions.
6. These contributed to the new generation of ten solutions which includes the offspring and two best solutions.
7. The best two solutions are included to make sure that the best data is available for the next iterations.
8. Now evaluated these 10 solutions and repeated the above procedure till the solution is converged.
9. The converged solution at 5^{th} iteration was V2= 1.10200 delta2= -8.00000 delta3= -13.0000
   And the error obtained is 1.1038

By calculating for different topologies of a 3 Bus system, the results using GS method and using GA are found as follows

	Topology 1		Topology 2		Topology 3		Topology 4		Topology 5	
	GS	GA	GS	GA	GS	GA	GS	GA	GS	GA
V2	1.115	1.115	0.89	1.115	0.99	1.002	0.981	1.002	1.58	1.08
δ2	-1.109	-1.109	-2.35	-1.109	-1.08	-7.9	-1.009	-7.9	-10.68	-2
δ3	-6.048	-6.048	-6.052	-6.038	-18.57	-13	-18.43	-13	-0.622	-14
Fitness	0.9059	0.9059	0.0551	0.2710	0.104	0.212	0.056	0.1217	0.013	0.283

6. Conclusion

The results are obtained from the program using MATLAB for power flow analysis using Gauss Seidal method and by Genetic Algorithm. It can be concluded that GA gives global minima using random initial population and gives faster convergence than GS method. The number of iterations required for convergence in GA is very less as compared to GS method.

7. References

[1] D. P. Kothari, I.J.Nagrath, "Power System Engineering ", Tata McGraw Hill publication 2008
[2] Hadi Sadat, "Power System Analysis", Tata McGraw Hill publication
[3] Haldar , chakrabarti, "Poweer System Analysis , Operation and Control", 2nd edition, PHI publication
[4] Allen J. Wood and B.F. Wollenberg, "Power Generation, Operation and Control", John Wiley and Sons
[5] D.E. Goldberg, "Genetic Algorithm in Search Optimization and Machine Learning", Addison – Wesley Longman,1989
[6] K. Deb, "Optimization for engineering design algorithms and examples," PHI, 2002.
[7] H. W. Dommel and W. F. Tinny, "Optimal power flow solutions," IEEE trans. on power app & systems, 87, 1968, pp 1866-1876.
[8] K. Iba, "Reactive power optimization by genetic algorithm," IEEE trans. on power systems, Vol. 9 No. 2, 1994, pp 685-692.
[9] W.D. Stevenson Jr., 'Elements of power system analysis', (McGraw-Hill, 4th Edition, 1982).
[10] K.F. Man, K.S. Tang, and S. KWong, 'Genetic algorithms: concepts and applications', IEEE Transactions on Industrial Electronics, 43 (1996), 5, pp. 519 - 533.
[11] M. Gen, and R. Cheng, 'Genetic algorithms and engineering design', (John Wiley & Sons, Inc., 1997).
[12] J.X. Xu, C.S. Chang, and X.W. Wang, 'Constrained multi objective global optimisation of longitudinal interconnected power system by genetic algorithm', IEE Proceedings, Generation,Transmission & Distribution, 143 (1996), 5, pp 435-446.